CHAPTER 5: Operation Part 7 Natural Gas Burners [4b of 5]

4b- CONSIDERATION OF THE NATURAL GAS SUPPLY SYSTEM TO THE BURNER

Given the importance of supplying natural gas to the burner (since combustion chamber explosions are extremely dangerous), a process that requires the use of pressure regulators, it is necessary to have **gas safety shut-off devices.**

Any gas leak entering the boiler combustion chamber through the burner when it is off or shutting down is extremely dangerous, as is the pressure regulator supplying too high or too low a pressure to the burner.

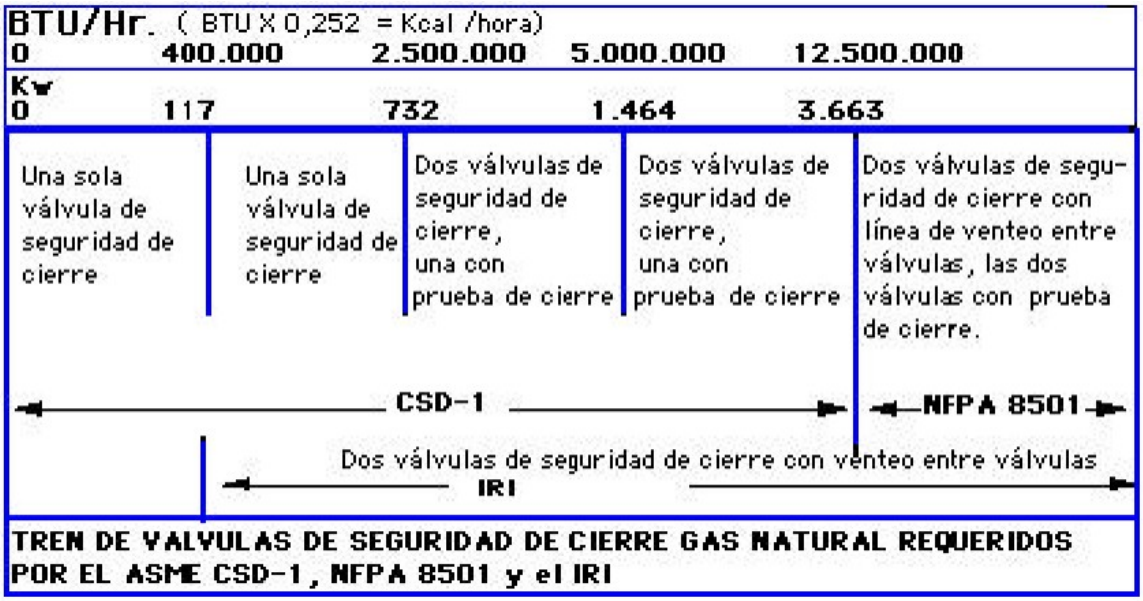
It is also essential to check that the valves are functioning correctly (both by visually verifying whether they are open or closed, and by having the electrical controls checked with a microswitch, using automatic venting devices in case of seat failures, such as low and high gas pressure switches).

In the case of safety shut-off valves; at least two must be installed in boilers of more than 630,000 Kcal/h (2,500,000 BTU/h or approximately more than 1,050 Kg/h of steam), in addition to the natural gas feed regulating valve to the burner (which will be in mechanical relation with the combustion air regulating valve or butterfly, in order to maintain the air/fuel ratio).

The following table lists the standards recommended by the National Board (United States), which incorporates standards from IRI (Industrial Risk Insurers), ASME CSD-1 (American Society of Mechanical Engineers, **Controls and Safety Elements for Automatic Boilers 1992**), and NFPA 8501 (Single Burner Operation of Boilers 1992).

Of course, this is for the USA, but it accurately reflects the safety issues with natural gas boilers.

Original table from “Pequeño Manual del Foguista” and english translation.



BTU/Hr (BTU x 0,252 = Kcal/hora)				
>0 BTU/Hr	400.000	2.500.000	5.000.000	12.500.000
>0 KW	117	732	1464	3663
A single safety shut-off valve	A single safety shut-off valve	Two safety shut-off valves, one with a shut-off test	Two safety shut-off valves, one with a shut-off test	Two safety shut-off valves with vent line between valves, both valves with shut-off test
CSD-1				NFPA 8501
	Two safety shut-off valves with inter-valve venting IRI			
NATURAL GAS SHUT-OFF SAFETY VALVE TRAIN REQUIRED BY ASME CSD-1, NFPA 8501 AND IRI				

In Uruguay, Argentine and European standards have been applied.

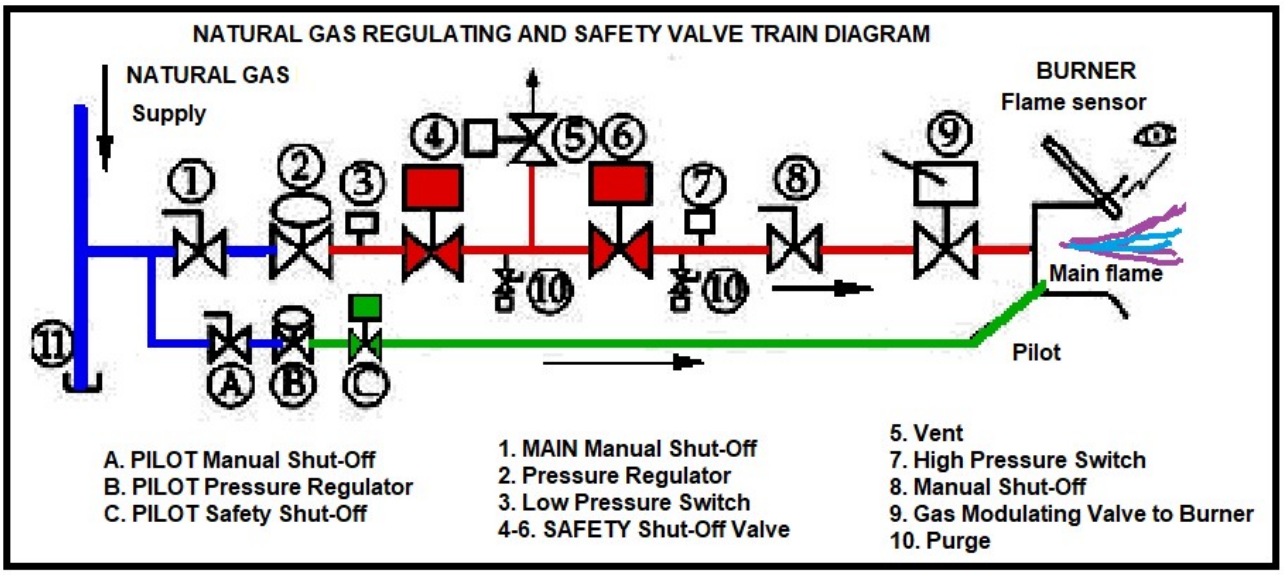
Given the purpose of this manual (general information), we will describe an installation according to American standards (NFPA 8501) to provide an overview of a system with medium capacity. However, we will also incorporate the Argentine standards (ENERGAS) applicable in Uruguay.

Let's now look at a sketch of a natural gas feed train (a simple example with minimal requirements according to some standards; later we'll see a more concrete example, accepted by NFPA 8501 for boilers over 12,500,000 BTU, or approximately a boiler producing more than 5,000 kg/h of steam).

In this sketch, we'll see two safety shut-off valves (which immediately cut off the gas supply, in less than 1 second, to the burner in case of low or high gas pressure failures, control the gas flow to ignite and shut off the

burner, shut off the burner due to low water level, lack of pilot light, lack of main flame, or insufficient combustion air pressure, as well as other controls necessary for startup and maintenance: minimum flame position for startup, closed valves, acceptable electrical voltage, etc.)

And the necessary components (such as those recommended by the IRI standard for boilers with burners over 100,800 BTU). Kcal/h (400,000 BTU/h) equivalent approx. to a boiler of more than 150 Kg/h of steam.



NATURAL GAS REGULATING AND **SAFETY VALVE TRAIN** DIAGRAM

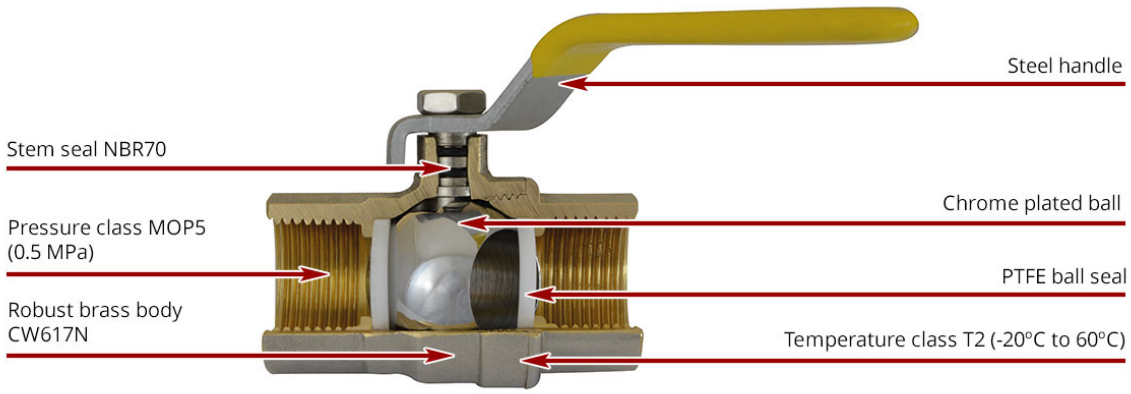
Natural gas arrives through the supply line at a higher pressure than the burner will use. It generally **carries contaminants that can pollute the gas** (such as oxide particles and metallic particles from the pipes and fittings), as well as condensation. There may be a filter, but the important thing is that there is **a vertical drip leg (also known as a collection, storage, and purge plug, shown as #11 on the drawing)** that will collect these debris, those undesirable substances (and can be cleaned periodically).

The gas will then go through two paths;
1) the pilot flame feed (manual valve "A") and
2) the main gas feed (manual valve "1") to the burner (main combustion).

This may vary in some cases. Both supplies will have a manual shut-off valve (the "A" for the pilot and valve No. "1" for the main flame), which allows for safe closure to enable work on maintenance and safe shutdown of the system.

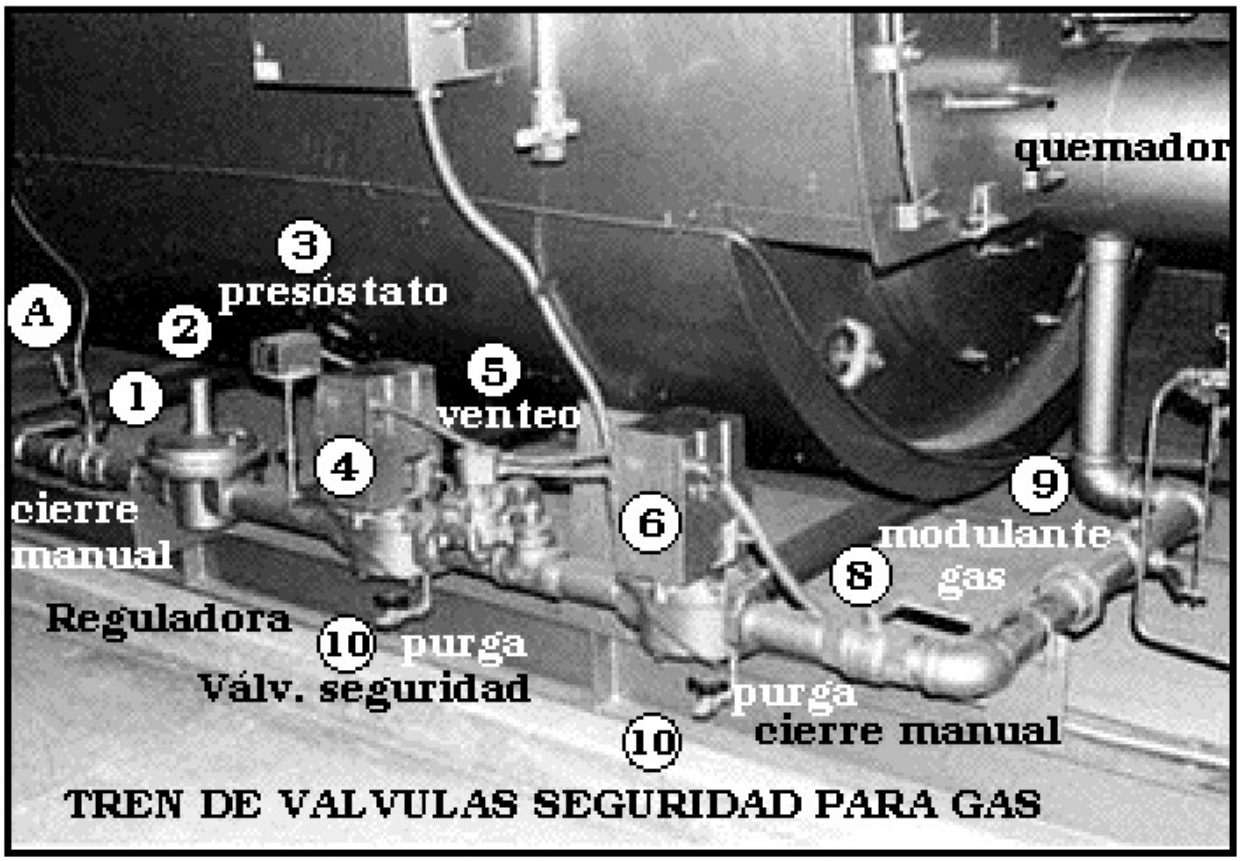
These valves are very important and must be quarter-turn (generally ball

valves suitable for gas, never use water or compressed aire valves).



GAS BALL VALVES, https://www.ferrocompany.com/family-29.html

There may be a pressure gauge indicating the supply pressure and then a pressure gauge in each regulated pressure section.



A. PILOT Manual Shut-Off
B. PILOT Pressure Regulator
C. PILOT Safety Shut-Off
1. MAIN Manual Shut-Off
2. Pressure Regulator
3. Low Pressure Switch
4-6. SAFETY Shut-Off Valve
5. Vent
7. High Pressure Switch
8. Manual Shut-Off
9. Gas Modulating Valve to Burner
10. Purge

NATURAL GAS **SAFETY VALVE TRAIN** EXAMPLE

Of course, outside the boiler room, there must be a manual valve to cut off the natural gas to the boilers (in the same way as in liquid fuel boilers, as well as a way to cut off the electricity).

The pilot light's fuel supply (which consumes very little compared to the main fuel) will also include its manual shut-off valve (A), a pressure regulating valve (B), and a **safety shut-off valve (C).**

Next, the burner's own fuel supply components will supply the pilot flame (generally, the **safety valve (B)** will consist of two solenoid valves, as we will see in a later example, with a vent between the valves if the power rating requires it).

We can divide the operation of a gas ignition pilot into three types:

- **"Continuous pilot"** (which remains permanently lit during service, and even when the main flame is not operating);

- **"Intermittent pilot"** (which ignites automatically each time it is necessary to ignite the main flame, turning off once the ignition time has ended);
and

- **"Intermittent pilot"** (which ignites automatically each time it is necessary to ignite the main flame and remains lit while the main flame is lit).

The gas pilot light accounts for a small percentage of the main gas consumption. Generally less than 3%, although in "small" boilers there may be direct-ignition burners with an electric spark from the main flame. Up to about 100,000 kcal/h, the main flame can ignite at its full nominal value, with a maximum ignition spark of 3 seconds,

then reaching a maximum of about 500,000 kcal/h. to "start" with a lower value than the total capacity, between 30% up to 300,000 kcal/h, and a maximum flame of 20% at startup, up to a maximum of 500,000 kcal/h of power.

For this reason, a burner with "direct start" using an electric spark is not permitted, in order to avoid a "backfire" due to ignition delay. The maximum attempted ignition time of the "electric spark" is no more than 3 seconds (in accordance with Argentine standards).

The same principle applies to gas pilot boilers. The higher the boiler's power output, the lower the percentage of the main flame used at startup, reaching values of up to 20% of the total capacity.

The pilot flame is no more than 3% of the main flame capacity (igniting at 100% of the main flame up to 100,000 kcal/h, 35% of the main flame up to 300,000 kcal/h, and a maximum of 20% of the main flame above 300,000 kcal/h).

The safety gas supply valves open slowly (taking at least 10 seconds up to 10,000,000 kcal/h and opening more slowly thereafter, no less than 20 seconds). However, they close quickly, in less than 1 second, thus preventing a backfire due to delayed ignition. lighting the main flame.

Here, the gas pilot, ignited by an electric igniter, generally has a longer **ignition safety time, lasting 15 seconds up to 300,000 kcal/h**. Above this value, the time decreases to a maximum of 10 seconds.

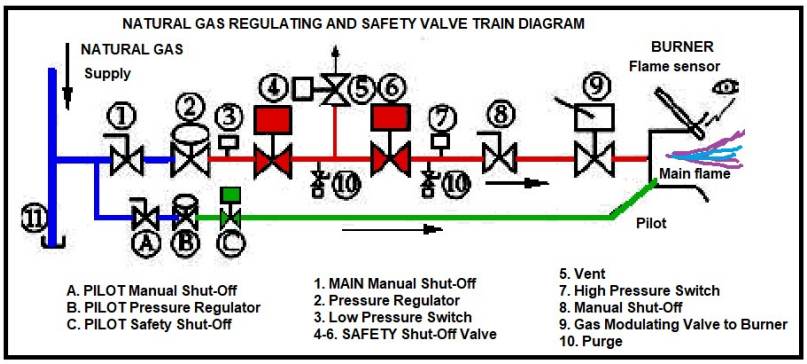
The electric igniter operates for a shorter time, resulting in a gas pilot flame stabilization period of approximately 5 seconds. This allows for monitoring the pilot flame to ensure it is properly functioning before the main flame safety valves begin to open slowly.

For safety reasons, flame control for both the pilot and main flames will cut off combustion at the safety valves, which will close in less than 1 second at 300,000 kcal/h.

Once the pilot flame capacity exceeds 50,000 kcal/h, a double automatic valve safety system with venting between the two valves will be installed.

Reignition or restart of the burner is only permitted if 1 second has elapsed since the flame extinction failure, in boilers up to 100,000 kcal/h. Reignition or restart is not permitted in higher-power automatic boilers (which must shut down in less than 4 seconds, the sum of all flame control and safety valve times).

A post-purge of approximately 15 seconds or more is required to expel any unignited gases.



The main gas supply to the burner will have a manual shut-off valve (No. 1), followed by a pressure regulator (No. 2).

A minimum pressure switch (No. 3) will monitor the gas pressure (switching off the burner if this occurs, but it cannot reset itself; it must be reset by the operator, who will check the supply and regulated pressures before resetting the pressure switch).

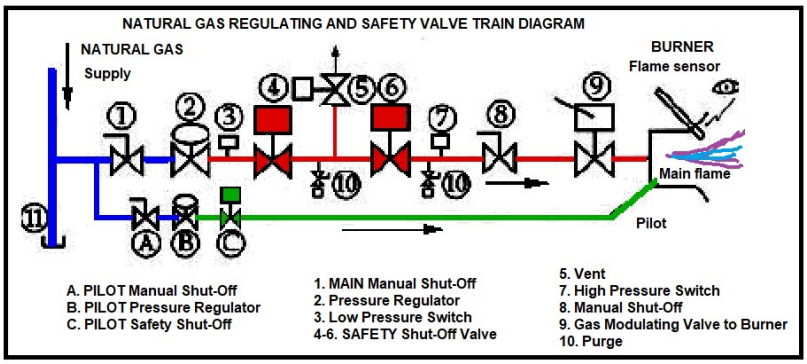
For safety shut-off, there will be two valves (No. 4 and No. 6) that are generally quick-closing (and slow-opening; this slow opening time will increase with increasing fire power, for example: up to 10,000,000 kcal/1000 kcal, no less than 10 seconds of opening time, and above this value, no less than 20 seconds.

This is very important to establish the flame smoothly and not abruptly, which could cause a backfire).

The valve will close in less than 1 second when the fire power requires it, and at a given fire power level (see table above), there will be an indicator showing the valve's status (open or closed).

To ensure that the first safety shut-off valve No. 4 (in case the seat doesn't close properly) there will be a vent valve (No. 5) that will open each time valve (No. 4) closes (venting the gas trapped between the two safety shut-off valves).

This way, if the second safety shut-off valve (No. 6) fails to close. Thanks to the venting, since there is no gas pressure between the two shut-off valves, the gas will not pass through valve (No. 6) to the burner, but will instead be released to the atmosphere through the vent (which can be dispersed or burned in a special device in a safe area, outside the boiler room).



After the second safety shut-off valve, there will be a pressure switch (No. 7) that will shut off the burner if the gas pressure exceeds the set point (it also needs to be manually reset, since once it shuts off the burner, it will not allow it to restart if the boiler operator (does not reassemble it manually).

Next, between the fuel line and the burner, there will be a manual shut-off valve (No. 8), which allows manual gas shut-off to the burner's gas regulator. (This allows testing of the regulation and safety shut-off system, including the pilot light, without the burner being ignited or supplied with gas.)

Next, there will be a valve that regulates the natural gas to the burner (No. 9), according to the gas requirements based on the steam boiler pressure or the hot water boiler temperature.

There will be drain valves in the lower sections of the fuel line (No. 10), which allow condensate to be removed (or gas leaks can be tested by observing the bubbles in a container of water. A flexible tube is connected to the valve, and the end of the tube is submerged in the water in a jar. Based on the number of bubbles per minute, a maximum permissible leak limit can be established.)

In smaller boilers, "monoblock" valves with leak testers for the main valves may be available.

The burner will also have the necessary safety features (monitoring of the pilot and main flames, cutting off the gas supply by closing safety valves No. 4 and No. 6 within 4 seconds of flame failure, totaling all times, but the valves themselves must close in less than 1 second).

Adequate purging times to properly vent the gases before ignition (generally no less than 4 air changes inside the combustion chamber and pipes, or 90 seconds, with the damper open 60%) and a post-purge upon shutdown (venting the combustion gases after extinguishing, preventing their

accumulation inside the combustion chamber, as these gases may contain unburned fuel).

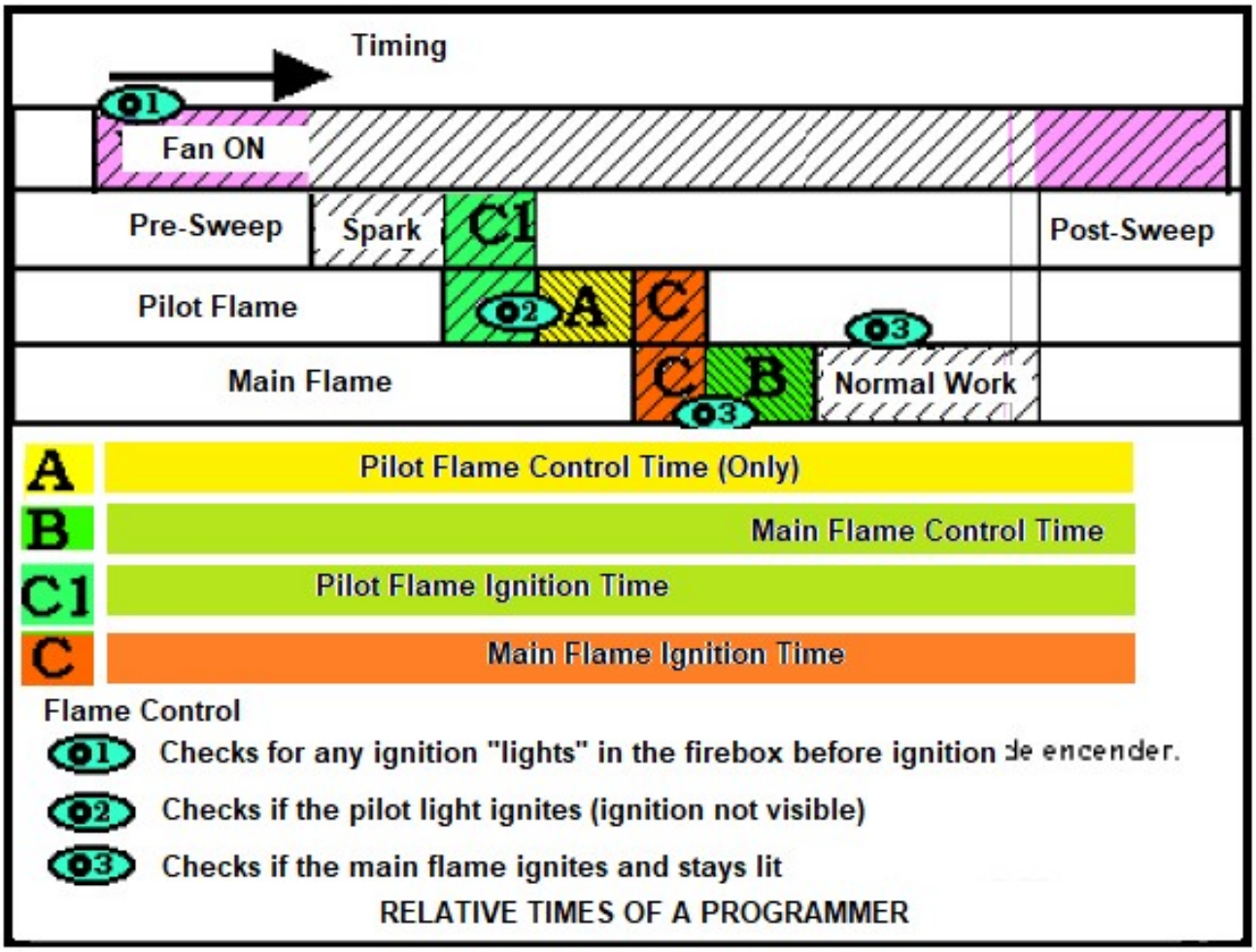
To this must be added another series of "tests" or "checks" that the programmer must and can perform, both while the system is running and stopped, and especially before proceeding to "start" it up (such as a microswitch indicating that a safety shutoff valve is closed, that the system is in the minimum starting position, or that the modulating motor has set the air control and gas valve to the minimum, generally less than 25% of total capacity, that the photocell does not detect any flames or visible fires inside the combustion chamber, that there is air pressure in the burner's air supply, etc.).

And then all the other control and safety elements of the boiler itself (control pressure switch or thermostat, maximum safety limit pressure switch and thermostat, water level sensor (generally dual), etc., such as the "interlock" systems for the circulation pumps in hot water boilers or the "sensors" indicating oil circulation in hot oil boilers). thermal).

COUNTER EXPLOSION IN NATURAL GAS BOILER

As we have seen, this system allows us to test each of the parts in order: the main or power flame train, without feeding the burner (closing No. 8, and without the "pilot" flame by closing A), test only the pilot flame igniter (and with it the sweep time and the sweep mechanisms and minimum and maximum air position, the safety microswitches of "safety valves closed", no presence of ignition sources before ignition, etc.), then test the gas ignition "pilot" in its "safety time" (that is, with the electric igniter already cut off),

But with the pilot gas flame lit (A in the diagram below), which if the photocell doesn't "see" it, the burner cuts off the pilot flame in the "safety" seconds and the burner remains "locked"), and then enabling valve No. 8 of the main gas supply, the entire burner is tested (in which the main flame will have its "safety time" (B in the diagram below) in which the auxiliary gas pilot flame has already gone out.



In short, the "programmer" will perform a series of checks depending on the brand and standards it complies with. Generally, before starting an ignition cycle, it performs a series of checks:

Once the steam pressure switch (or hot water thermostat) "closes," giving the command to ignite the burner (but the level controls, both the pressure limit switch, and other limits, such as closed gas safety valves, safety valve leak testers, etc., must also be enabled), the following occurs:

1- that the **air supply fan is running and there is combustion air pressure**;

2- that there is **no "visible" flame** to the flame detector from any point inside the combustion chamber (note, it must be visible to the flame sensor, whatever it may be; therefore, there may be flames in non-visible areas, which can cause explosions, because the boiler is dirty with soot from having operated on fuel oil or due to poor combustion of the natural gas itself);

3- Check that the **gas supply valves are closed**;

4- Perform a **purge of the combustion chamber and flue area** with several air changes (no less than 4 changes or 90 seconds with the air supply fully open), after verifying that there is air pressure in the burner's air chamber (air pressure sensor);

5- Verify that the purge was performed with the **air supply fully open** or at least 60% open (using a fully open microswitch);

6-a Before starting the flame ignition cycle (spark igniter, auxiliary pilot, and main flame), check if the **air and fuel modulation valve are at the "minimum start-up"** setting (generally less than 25% of the burner's total power).

6-b **Light the electric igniter for a few seconds** (first, depending on the model, the igniter alone, usually for about 3 seconds), then cross-light the auxiliary pilot gas to ignite it. In any case, the flame sensor must not detect the electric spark (or any other heat source) at any time to avoid errors.

6-c **Light the auxiliary gas pilot flame** (from a cylinder or piped gas, which, monitored by the flame sensor, should generally ignite for a maximum of 3 to 5 seconds (time C 1), or according to regulations; sometimes cylinder gas is preferred for the pilot because it has a "hotter" flame and is more visible). Turn off the igniter, leaving only the gas pilot under the control of the flame detector for a few seconds (check if the pilot flame is stable, generally for a maximum of 5 seconds (time A), depending on many factors).

7- Then the **main flame is lit at the "minimum" setting** (ensuring that the minimum and maximum gas pressures are within operating parameters from the moment the main flame is enabled, the safety valves open slowly and the gas modulation valve is at its minimum, which is usually less than 25% of the total capacity),

and **the pilot flame goes out after a few seconds**, making a "crossover" of contact time with the main flame's gas (from 3 to 5 seconds, depending on time C) so that the main flame has a relatively short time to ignite.

If it doesn't ignite immediately (the flame sensor detects it in less than 1 second to a maximum of 3 seconds; if the flame is not detected, it cuts off the gas safety valves, which close in less than 1 second),

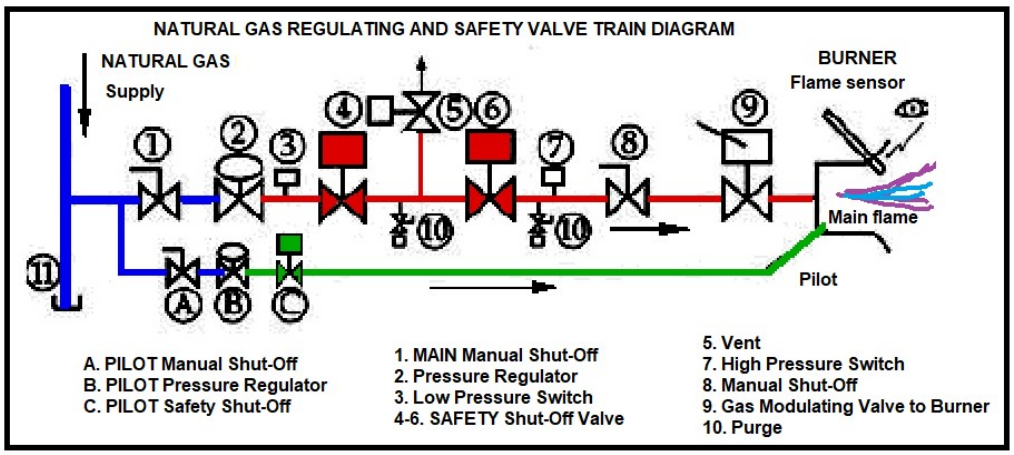
the burner shuts off and performs a "post-purge" to "sweep" away the unignited gases (the burner remains "locked" until the operator identifies the cause of the failure and then **T**

he programmer then "resets" itself, thus becoming aware that there is a fault. Faults will be indicated in different ways depending on the programmer (on an electronic display, or by indicating when the lockout occurred if it is a "rotary" programmer, etc.).

If the burner ignited normally, there is a waiting period for the flame to stabilize (usually 3 to 5 seconds, time B). Only after this period does the burner begin to modulate, **drawing fuel according to the command from the pressure switch or modulating thermostat.**

When the boiler pressure causes it to shut down due to a "steam pressure cutoff" (a pressure switch) or its temperature (a thermostat), the burner shuts off (before reducing to the minimum if it is modulating) and performs a "post-purge" to expel any remaining gases. Since the mixture is "lean," this can cause a "delay" explosion.

In this case, the burner is ready to begin a new normal ignition cycle.



Gas shut-off safety valves (4) (6), usually consisting of 2 valves (or a double valve in the same body in small boilers), open "slowly" (several seconds) and must close "quickly" (usually less than 1 second).

These valves must have a "vent" (5) between them to the atmosphere or to a vent manifold that carries the gas to a safe place (which will go to the atmosphere if possible or where it is burned with a pilot flame) when they are closed, so that there is no loss of gas into the home.

Other systems, instead of vents, have a valve leak test system (there is more than one test system: one uses a small gas pump to raise the pressure a few millibars above the normal pressure between the two closed valves and uses a pressure switch to monitor whether the pressure drops within a certain time;

another consists of testing the two safety valves step by step, checking that the pressure does not drop between the valves within a certain time. This tests the valve closest to the burner, or, by "emptying" the gas between the valves, it checks that the pressure does not rise due to a leak in the first valve).

In "small" burners, the valves may be in the same "body," with the test or vent system included, etc.

It is very important that the safety valves for the main flame (4) (6) and the pilot flame (C)do not allow gas to enter the combustion chamber under any circumstances if they are closed, as this could cause a combustion chamber explosion.

Once the burner is properly lit, the air-fuel ratio must be adjusted throughout the burner's operating range.

Taking care **not to exceed the maximum combustion power** as this can cause the tubes, which are either mandrel-grooved or mandrel-grooved and welded to the hot plate, to loosen.

Remember that the natural gas flame is not very visible for visually adjusting the air-fuel ratio.

It is advisable to have instruments that measure excess air (between 10% and 20%) and ensure good combustion by measuring unburned gases (or carbon monoxide, CO, which should be less than 400 ppm, approximately 0.04% CO, although a good burner should show a near-zero CO reading).

Unburned gases can be present due to insufficient air or a combustion problem (poor gas-air mixture, combustion chamber too small for complete combustion, very cold flame, etc.).

Remember that the air-fuel ratio (excess air relative to gas) changes if the gas regulator pressure changes (if the gas pressure rises, there will be less air, and if the gas pressure falls, there will be excess air).

Natural gas generally doesn't produce smoke from the chimney, but it can produce soot (very fine and highly insulating, which can even contribute to a fireplace explosion).